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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF ENTOMOLOGY—BULLETIN No. 105.
L. O. HOWARD, Entomologist and Chief of Bureau.

THE ROCKY MOUNTAIN SPOTTED FEVER TICK.

WITH SPECIAL REFERENCE TO THE PROBLEM OF ITS CONTROL IN THE BITTER ROOT VALLEY IN MONTANA.

BY

W. D. HUNTER,
In Charge of Southern Field Crop Insect Investigations,

AND

F. C. BISHOPP,
Entomological Assistant.

[In Cooperation with the Biological Survey and the Montana Agricultural College.]

ISSUED NOVEMBER 17, 1911.

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T. C. Barber, C. E. Hood, *engaged in sugar cane and rice insect investigations.*
R. A. Cooley, D. L. Van Dine, Wilmon Newell, A. F. Conradi, C. C. Krumbhaar, *collaborators.*

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The important papers of Dr. Ricketts have recently (May, 1911) been reprinted by the University of Chicago Press in a memorial volume entitled "Contributions to Medical Science."

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THE ROCKY MOUNTAIN SPOTTED-FEVER TICK, WITH SPECIAL REFERENCE TO THE PROBLEM OF ITS CONTROL IN THE BITTER ROOT VALLEY IN MONTANA.

INTRODUCTION.

For many years a disease of human beings, known as spotted fever, has been known to occur in certain localities in the Rocky Mountain region of the United States. In fact the evidence is rather conclusive that the disease existed before the settlement of the country by white men. At any rate old residents of the Bitter Root Valley in Montana have informed us that the first white settlers were warned by the Indians of the danger of contracting a very serious disease if they visited certain localities. From what has been learned in recent years it is evident that these dangerous localities are the very ones in which spotted fever is now most prevalent.

The States in which the disease occurs most frequently are Montana and Idaho. There is no doubt, however, that it occurs in at least portions of other States, such as Oregon, Washington, Nevada, Utah, Wyoming, and Colorado.

Definite work on the nature and method of transmission of spotted fever was not begun until 1902. In that year Drs. Wilson and Chowning announced the theory that the "wood tick" is the natural agency through which the malady is transmitted from one human being to another. This hypothesis was based upon three observations: First, that the majority of cases of spotted fever showed histories of tick bites; second, that the localities in which the disease was most frequently contracted were those where ticks were most abundant; and, third, that the season of spotted fever coincided with the period when the ticks were most frequently observed. Drs. Wilson and Chowning had no facilities for proving their hypothesis in a scientific manner, but such proof was soon obtained. According to the late Dr. H. T. Ricketts[1] the first experiments which resulted in proof of the transmission of spotted fever by the tick were conducted by Drs. McCalla and Brereton, of Boise, Idaho, in 1905. In these experiments a tick which was found attached to a spotted-fever patient was removed and allowed to bite a healthy person. In

[1] Fourth Biennial Report, Montana State Board of Health, p. 106.

eight days this person developed a typical case of spotted fever. The experiment was continued by allowing the same tick to bite a second person. In this case again a typical case of spotted fever resulted. The results of the important experiments of Drs. McCalla and Brereton were not published by them.

In 1906 Dr. H. T. Ricketts, then connected with the University of Chicago, began a series of investigations which must always be considered classic. Not being aware of the experiments of Drs. McCalla and Brereton, Dr. Ricketts started with the hypothesis of Drs. Wilson and Chowning. His first work was devoted to determining whether guinea pigs and rabbits are susceptible to the disease and consequently suitable for inoculation experiments. The original experiments with rabbits were somewhat inconclusive, but it was found that the injection of blood from a human being suffering with spotted fever invariably brought about the disease in guinea pigs. In fact in these animals the disease was found to run a course very similar to that in human beings. It was thus determined that guinea pigs were suitable subjects for experiments to determine whether ticks could transmit the disease. On August 4, 1906, Dr. Ricketts announced the results of the first experiment in the tick transmission of the disease. A small female tick was placed on a guinea pig which had been inoculated with the blood of a patient who died of spotted fever. The tick was allowed to feed on this inoculated guinea pig for two days. It was then removed and placed in a pill box for two days. At the end of that time it was allowed to attach to the base of the ear of another guinea pig which had not been inoculated with spotted fever. After three and one-half days the temperature of this guinea pig rose and remained above normal for more than seven days. The pig also showed practically all of the other symptoms of spotted fever. In fact, there was no doubt whatever that the guinea pig contracted spotted fever from the bite of the single tick. As a control on the experiment Dr. Ricketts placed two other guinea pigs in the cage occupied by the animal upon which the tick had been placed. They remained there for two weeks. These two pigs showed no indications whatever of fever. Thus the possibility of infection by contact or by feces was eliminated. The only difference between the conditions surrounding the pig which contracted fever and those surrounding the others was that the former was bitten by a fever tick.

During the following year (1907) Dr. Ricketts succeeded in transmitting the disease by ticks in a number of additional cases. In one experiment he found that the male tick as well as the female is capable of transmitting the disease. In other experiments it was determined that the larval or nymphal tick may acquire the disease and retain it through the molting period, and transmit the infection in the following stage to another host. The most interesting experi-

FIG. 1.—VIEW IN LO LO CANYON, WHICH LEADS INTO THE BITTER ROOT VALLEY, SHOWING CONDITIONS UNDER WHICH TICKS THRIVE.

FIG. 2.—CAMP LABORATORY NEAR FLORENCE, MONT., IN ONE OF THE MOST HEAVILY TICK-INFESTED REGIONS KNOWN.

TICKS AND SPOTTED FEVER IN THE BITTER ROOT VALLEY, MONT.

ments, however, were with adult ticks. It was found that when an adult becomes infected with the disease, the infection passes through the eggs developed in the tick, so that the young of the next generation may transmit the disease.[1]

The main points determined by Dr. Ricketts are as follows:

(1) Guinea pigs and certain other animals, as monkeys, are susceptible to spotted fever.

(2) Larval ticks applied to an infected animal contract the infection and are able to transmit it to the following or nymphal stage.

(3) Nymphal ticks feeding upon infected animals acquire the power of transmitting the disease as adults.

(4) Adult ticks are able to acquire the disease by feeding upon an infected animal and to transmit it through the egg stage to the succeeding generation.

(5) Infective ticks are to be found in nature.

The transmission of disease organisms through the egg stage of ticks is known in a number of other instances. It is the case with the tick *Margaropus annulatus* Say, which transmits splenetic fever of cattle in the southern portion of the United States. The causative organism of splenetic fever has actually been found in the eggs of this tick. Dr. Ricketts recently made a tentative announcement of the finding of the spotted-fever organism in the eggs of *Dermacentor venustus* Banks. Future investigation will undoubtedly result in certainty regarding this point.

Some of the main points determined by Dr. Ricketts were corroborated about the same time by Dr. W. W. King, of the Public Health and Marine-Hospital Service, whose results were published in the Public Health Reports of July 27, 1906.

WORK UPON WHICH THIS BULLETIN IS BASED.

The work of the Bureau of Entomology on the spotted-fever tick began in 1908, when the investigation of the life history and habits of the species was undertaken. Plans were made for determining the distribution of the tick and for the exhaustive life-history investigations necessary in the formulation of plans of control. Following the plan for determining the distribution of the tick, two men were selected, one to travel through the southern Rocky Mountain region and the other through the northern. The late Mr. F. C. Pratt made investigations in New Mexico, Arizona, southern California, and Colorado. Mr. W. V. King, whose work as an agent of the bureau began July 1, 1909, made the investiga-

[1] The Rocky Mountain spotted-fever tick, like a number of other species, exists in four distinct stages, namely, egg, larva, nymph, and adult. The eggs are invariably deposited on the ground in large masses. The larvæ which emerge from the eggs are minute six-legged animals. After feeding upon a suitable host, they drop to the ground and molt, becoming nymphs. In this stage they have eight legs. The nymph waits until it can attach to a host, engorges blood, drops, molts its skin, and becomes adult.

tions in the northern Rocky Mountain region. He explored Wyoming, Idaho, portions of Utah, and Oregon and Washington. Prof. R. A. Cooley, of the Montana Agricultural College, consented to cooperate with the bureau by directing the work of Mr. King and by submitting specimens from many localities in Montana. During 1909, Mr. J. D. Mitchell, of the Bureau of Etomology, visited New Mexico, and succeeded in determining the southernmost locality in which the fever tick is at present known to occur.

The life-history work upon the tick was conducted at Dallas, Tex., by Messrs. H. P. Wood, G. N. Wolcott, and the junior author. This began early in 1909 and has continued without interruption.

In February, 1910, a conference was held in Washington, D. C., with Prof. R. A. Cooley and Dr. C. Hart Merriam, then Chief of the Biological Survey, for the purpose of formulating definite plans for the continuation of the work. It was agreed that the determination of the range of the tick should be continued by correspondence rather than by sending men into the field and that the local aspects of the problem in the Bitter Root Valley should be investigated by placing an agent there. The Bureau of Entomology provided the necessary funds and established a laboratory near Florence, Mont. (See Pl. I, fig. 2.) Prof. Cooley agreed to supervise the work in Montana, and was appointed a collaborator in the bureau on March 1, 1910. At the same time Mr. W. V. King was appointed to work under the direction of Prof. Cooley in the Bitter Root Valley. This plan of cooperation has continued down to the present time.

The results obtained have been due, to a large extent, to the energy and acumen of Prof. Cooley and to the high grade of Mr. King's work. But a special word must be said about Mr. King. Undeterred by the possibility of contracting spotted fever, he located on an abandoned farm in the most dangerous locality known. In the immediate vicinity a number of deaths from spotted fever had occurred within a short time. He remained there throughout the season of 1910, subject to the risk of contracting the fever on his daily trips into the field or from the ticks used in the experiments at the camp laboratory. His devotion to the investigation outweighed all considerations of personal safety. Great credit must also be given Mr. C. Birdseye and Mr. A. H. Howell, of the Biological Survey, for assuming the risk of residence at the laboratory during a portion of the season of 1910. Mr. Birdseye continued the investigation of the mammals of the valley in 1911.

In addition to the work in cooperation with the Montana Agricultural College, in 1910, the bureau undertook to obtain information regarding the exact extent of the area in which the spotted-fever tick occurs. By means of a system of circulars and the generous cooperation of many physicians and other persons throughout

the Rocky Mountain region, a very large amount of information was obtained. In fact the correspondents sent in altogether 1,400 lots of ticks, 850 of which were of the fever species. These represented 225 localities in California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming.

Very many of the ticks received during the course of this work were in immature stages. Unfortunately our present knowledge of ticks is not sufficient to enable us to determine the species to which immature forms belong. This necessitates very special care in rearing to maturity the immature forms received. This work was done at Dallas, Tex., and naturally involved a large amount of skilled attention.

The information now in hand regarding the spotted-fever tick was greatly increased through the cooperation of the Biological Survey of this department. In 1910 two agents of this survey, Messrs. A. H. Howell and C. Birdseye, were located at the camp laboratory of the Bureau of Entomology near Florence, Mont. These agents were engaged in the collection of wild mammals upon which one stage or another of the spotted-fever tick occurs. This work resulted in showing the relative importance of the different mammals found in the Bitter Root Valley and adjacent mountains as carriers of the spotted-fever tick. It also revealed many points having a bearing on the original source of the disease in nature and on other important matters. The Biological Survey has also studied carefully the possibility of the eradication or control of all the wild mammals which carry the fever ticks.

In September, 1910, Prof. H. A. Morgan, director of the Tennessee Experiment Station, consented to make a trip to the Bitter Root Valley and to advise the forces cooperating regarding the sufficiency of the data obtained and the feasibility of plans of eradication based thereon.

Of course the authors have made full use of the available literature on the investigations that have been conducted by other persons. Most useful have they found the first and second spotted-fever reports of Dr. H. T. Ricketts, published in the Fourth Biennial Report of the State Board of Health of Montana.

POSSIBILITY OF INCREASE OF AREA OF SPOTTED FEVER.

The approximate area in which spotted fever occurs has been indicated in a previous paragraph. Since it has been shown, however, that a certain tick (*Dermacentor venustus* Banks) is the only known agent of transmission of the disease in nature, it follows that the possible area in which spotted fever may occur is at least coincident with the range of the tick, exactly as the possible range of yellow fever is as extensive as is the area in which the mosquito

which transmits it is to be found. Extensive work conducted by the Bureau of Entomology has shown with considerable accuracy the area in which spotted fever may be thus propagated. The map (fig. 1, p. 16) shows the area in which the necessary agent for transmission occurs, and consequently the possible geographical distribution of the disease. This map is based upon the examination of 850 lots of spotted-fever ticks received from 230 localities during the seasons of 1909, 1910, and 1911.

One of the most remarkable features of spotted fever is the fact that strains of different degrees of virulence exist in different localities. In Idaho the death rate is from 5 to 7 per cent. In the Bitter Root Valley in Montana, however, the death rate is about 70 per cent. One consideration which has caused the Bureau of Entomology to concentrate its efforts in the Bitter Root Valley is the possibility that the virulent form of the disease, now restricted to that valley, may eventually be carried into other regions where the presence of the tick would make transmission possible.

There are several ways by which the virulent strain of the disease might be carried out of the Bitter Root Valley. It could be taken either by ticks or in the blood of human beings. Carriage by ticks might occur when these animals are transported on men, horses, or cattle. Moreover, tick eggs or other stages of the tick which have been shown to contain the disease organism might be transported in hay or other commodities. There is also a chance that ticks in various stages might be transported on the hides of domestic or wild animals.

As regards carriage of infection in the blood of human beings, our conclusions are largely theoretical. It is not known how long the blood of a person who is attacked with spotted fever remains infective. It is probable, however, that it is infective for some days before the height of the fever and for some time thereafter. During the period either preceding or following the climax of the disease a person might leave the Bitter Root Valley. If in another locality he should be bitten by the fever tick and the specimen should escape, the establishment of the virulent form of the disease would be accomplished. In certain diseases similar to spotted fever, such as splenetic fever of cattle, the organism of the disease remains in the blood for many years without causing an acute or noticeable attack. Nevertheless, all ticks which feed upon these apparently immune animals become infected and can transmit the disease in acute form to other animals. Although nothing is known as to the persistency of the organism of spotted fever in the blood of persons who have apparently recovered, there is a possibility that it may remain for some months or even years. In this way there is a probability of

considerable extension of the territory in which the virulent form of the disease occurs, by migration out of the valley.

Naturally the chances of spread will increase with the development of the Bitter Root Valley and the growth of shipments of cattle or movements of people to other regions. These considerations are sufficient to justify very energetic means for control where the virulent form of the disease now occurs and where, as will be shown in this bulletin, the practical eradication of the tick, and, consequently, of spotted fever, is entirely feasible.

It has been shown by experiments conducted in the Institute of Infectious Diseases in Chicago that several species of ticks other than the form which occurs commonly in the Bitter Root Valley are capable of transmitting spotted fever. A very hopeful feature of the situation, however, is that in the valley there is but one tick species which attacks man. Therefore the other species are of no practical importance as regards spotted fever. Even among the species which feed upon the lower animals there are many thousands of specimens of *Dermacentor venustus* to every one of all other varieties. Moreover, means of control of this one species, such as will be described in this bulletin, will serve greatly to lessen the number of the other forms. For these reasons, in formulating plans for practical eradication it is necessary to consider only the one dominant tick in the valley.

There is one respect, however, in which the discovery that species other than *Dermacentor venustus* can transmit the disease may be of importance. The other forms occur over wide areas in the eastern and southern portions of the United States. It is conceivable that if the disease were once introduced in the blood of a human being or otherwise, the other ticks might propagate it and transmit it in regions far outside of the territory in which the fever is now known to occur. But the danger on this score is not so great as might be thought. In the first place, in no localities in the United States are any species of ticks as numerous as is the fever species in the Bitter Root Valley and elsewhere in the Rocky Mountain region. Consequently, the occurrence of anything like an epidemic of the disease would be impossible. Only occasional or rare cases could be expected. In the second place, it can not be foretold whether spotted fever would find general conditions suitable for propagation in localities outside of the Rocky Mountain region. Nevertheless the degree of danger from this source, while perhaps slight, emphasizes the importance of eradication of the spotted-fever tick in the mountain region and also of the discovery of effective means of control for all species of ticks wherever they occur.

IMPORTANCE OF THE CONTROL OF THE SPOTTED-FEVER TICK.

The most conspicuous loss from spotted fever is in human lives. In the Bitter Root Valley it was estimated in 1904 that 200 cases of the severe type of the disease had occurred up to that year. A conservative estimate of the mortality there, as has been stated, is 70 per cent. This means a loss of about 140 lives in this small valley. At the present time, with an increase in the population of the valley, it is estimated that about 20 cases of the disease occur annually. This means a loss of about 15 lives each year and this loss is certain to increase as the population of the valley becomes larger.

In Idaho it was estimated in 1908 by Dr. E. E. Maxey that the annual average of cases of spotted fever was 375. Undoubtedly, as Dr. Maxey pointed out, this estimate is very conservative. In all probability 500 would be a small estimate. The comparatively small mortality in Idaho would give a loss of human lives each year of about 35.

Taking into consideration the whole area over which spotted fever is more or less prevalent, it is conservative to estimate 750 cases each year with probably 75 deaths.

A great indirect injury the tick does in the Bitter Root Valley is in preventing the proper development of a region favored by a rich soil and by remarkable climatic advantages. As long as it is known that a dangerous disease exists there and that persons who farm or go into the country are especially subject to it, the valley can not prosper as it should. Relief from the tick would immediately result in increased land values and larger immigrations into the valley.

In a larger way the possibility of the spread of the virulent form of the disease outside of the valley must be considered. This alone would warrant a much larger expenditure than is actually required for extermination or control in the valley.

SUMMARY OF FACTS BEARING ON IMPORTANCE OF TICK CONTROL.

It has been proved beyond peradventure by the investigations of Dr. Ricketts and others that spotted fever is transmitted in nature only by certain ticks. In the region where the disease now occurs it is transmitted to man by a single species of tick. Therefore the rational method of eradicating the disease is to attack this tick. In this way the proper procedure is exactly analogous to that being followed in the eradication of splenetic fever of cattle from the United States, by the eradication of the tick which transmits it. In the case of splenetic fever, certain more or less effective means of combating the disease itself have been discovered. These are in the form of a method of preventive inoculation and the administration of certain

drugs. In spite of this it has been found that the only hope for the eradication of the disease, or even for practical control, is in the destruction of the ticks. Inasmuch as no means of preventing or curing spotted fever are known, the importance of attacking the ticks is much greater than in the case of splenetic fever. The situation is also analogous to that brought about by malaria and yellow fever, which, as is well known, are transmitted by certain mosquitoes. The control of these diseases in all parts of the world has practically resolved itself into a warfare against the mosquitoes.

These considerations seem to make it very evident that the logical course to follow in the eradication or control of spotted fever is the elimination of the tick. The problem becomes purely an entomological one. Under these circumstances, it is most fortunate that certain feasible and economical means of eradication, first outlined in a rather general way by Dr. Ricketts, have been placed upon an exact and certain basis by the recent investigations of the Bureau of Entomology.

DISTRIBUTION OF THE SPOTTED-FEVER TICK.

As is shown in the accompanying map (fig. 1) the range of the Rocky Mountain spotted-fever tick extends throughout the northern part of the Rocky Mountain region across the Great Basin to the eastern edge of the Cascade Range. The southernmost limit of the tick is in the northern edge of New Mexico. Although the distribution of the species in Canada has not been determined, there is little doubt that it extends over the southern half of British Columbia and the western portion of Alberta. However, only one accurate record of the occurrence of this species in Canada has been made, namely, by Dr. H. G. Dyar, who captured two female specimens at Kaslo, British Columbia, in 1903.

While infestation occurs throughout large portions of Montana, Idaho, Washington, Oregon, Nevada, Utah, Wyoming, and Colorado, comparatively small areas in New Mexico and California are infested. The tick probably occurs throughout the entire Black Hills region in South Dakota and Wyoming, although but one collection has been made in that region.

Naturally there is no uniformity in the abundance of the tick throughout the territory in which it occurs.

Our knowledge of the local occurrence of the tick throughout the Western States is not sufficiently complete to enable us to make definite statements as to areas within the whole infested region in which comparatively few ticks are to be found. We do know, however, that certain sections of the country which are unfavorable for the development of the species are only slightly or not at all infested.

During the investigation about 850 lots of the fever species have been collected. The following is a list of the counties and the num-

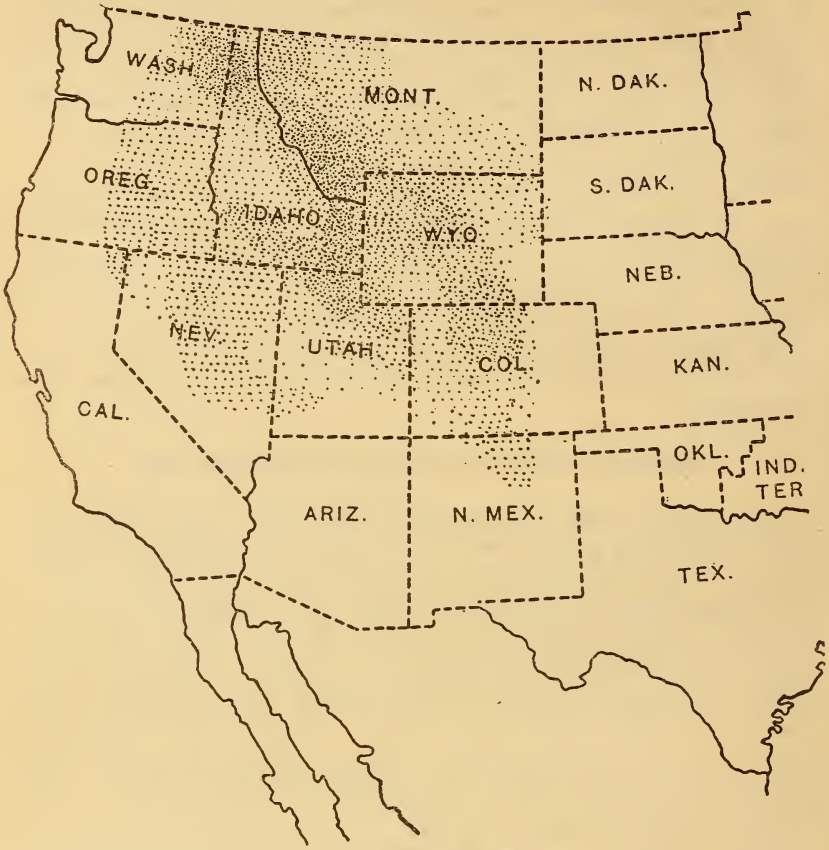


FIG. 1.—Map showing region in the United States in which the Rocky Mountain spotted-fever tick occurs. The degree of shading indicates the relative abundance of the tick in different sections. (From Bishopp.)

ber of localities within those counties where the species has been taken by the bureau:

NUMBER OF LOCALITIES, BY COUNTIES AND STATES, IN WHICH THE SPOTTED-FEVER TICK IS KNOWN TO OCCUR.

California.—Modoc County, 3; Lassen County, 1.

Colorado.—Boulder County, 4; Clear Creek County, 1; Eagle County, 1; Garfield County, 1; Gunnison County, 1; Jefferson County, 1; Lorimer County, 3; Mesa County, 2; Pitkin County, 1; Summit County, 1.

Idaho.—Bannock County, 7; Bingham County, 2; Blaine County, 3; Boise County, 1; Bonner County, 2; Canyon County, 1; Cassia County, 2; Elmore County, 3; Fremont County, 6; Kootenai County, 2; Lemhi County, 2; Lincoln County, 2; Oneida County, 4; Shoshone County, 1; Washington County, 1; Twin Falls County, 1.

Montana.—Beaver Head County, 3; Broadwater County, 2; Carbon County, 1; Custer County, 1; Flathead County, 4; Gallatin County, 5; Granite County, 5; Lewis and Clark County, 4; Lincoln County, 2; Madison County, 6; Meagher County, 3; Missoula County, 8; Park County, 2; Powell County, 3; Ravalli County, 7; Rosebud County, 4; Sanders County, 5; Silver Bow County, 1; Teton County, 2; Yellowstone County, 1.

Nevada.—Eureka County, 1; Humboldt County, 2; Lander County, 2; Lincoln County, 2; Nye County, 3.

New Mexico.—Rio Arriba County, 1; San Miguel County, 1.

Oregon.—Baker County, 1; Crook County, 3; Grant County, 1; Harney County, 3; Klamath County, 1; Lake County, 1; Malheur County, 2; Sherman County, 1; Umatilla County, 2; Union County, 1.

Utah.—Boxelder County, 2; Cache County, 2; Iron County, 1; Uinta County, 1; Utah County, 3; Wasatch County, 3.

Washington.—Asotin County, 2; Chelan County, 2; Douglas County, 1; Grant County, 1; Kittitas County, 1; Spokane County, 3; Stevens County, 14; Yakima County, 3.

Wyoming.—Albany County, 3; Bighorn County, 6; Carbon County, 3; Fremont County, 6; Latrona County, 3; Park County, 2; Uinta County, 2; Weston County, 1.

The above is far from being a complete list of those counties in which the spotted-fever tick occurs, yet it gives a definite idea of the territory infested. It should be understood that the number of localities given for a county does not represent the relative abundance of the tick in that county. The table includes only the number of localities from which the tick has actually been received. Greater population or a larger number of collectors in some counties has given more localities than in others, while the actual abundance of the tick may be exactly the reverse. Further investigation throughout the Rocky Mountain region will undoubtedly show the tick to be present in the majority of the counties included in the area shown to be infested in figure 1. Dr. E. E. Maxey[1] (1908, p. 4) reports that the tick has been found to occur in all of the counties of Idaho with the exception of Latah.

As is pointed out in Circular No. 136 of the Bureau of Entomology, the fever tick is known to occur at various elevations from slightly over 500 feet to nearly 9,000 feet above sea level. The species occurs in greatest abundance in the area known as the transition zone. It is also commonly found in the Canadian and Upper Sonoran life zones.

FACTORS INFLUENCING ABUNDANCE.

The occurrence and abundance of this tick within a given locality are dependent, to a large extent, upon the presence of favorable conditions for development. These conditions are, first, the existence of the small mammals which serve as hosts for the immature stages; second, the presence of large mammals upon which the adults may

[1] See Bibliography, p. 45.

engorge, and, third, the existence of a certain amount of protection for the development of the stages when not on hosts. As a rule the abundance of ticks is dependent upon the amount of vegetation. Lands upon which some fallen timber and undergrowth occurs are usually found to harbor ticks in abundance, provided the hosts—certain small mammals and domestic animals—are also present. In the Bitter Root Valley the areas in which more or less heavy second growth has followed the removal of the original timber have been found to be most heavily infested with ticks. These areas are locally known as "slashings." (See Pl. I, fig. 1.)

It has been determined that the direct rays of the sun during the summer have a markedly injurious effect upon the early stages of the tick. This fact may be utilized to some extent, as will be shown later, in the control of the species by clearing the land of timber and underbrush. In small experiments it has been found that when the seed ticks are exposed to the sun during very hot weather they immediately crawl down the grass to the surface of the soil to seek protection, and in the absence of an abundance of moisture death results in a very few days. The exposure of freshly deposited eggs to the sun at Dallas, Tex., has been found to cause them to shrivel and dry within less than a day's time.

The relative abundance of rain, especially during the spring months, in different years has a marked effect upon the number of ticks occurring in a given locality. This factor is of little importance in the natural control of the adult stage of the tick, but is a potent factor in the destruction of the eggs and immature stages, particularly after the latter have become engorged and dropped from the animal.

Several other natural means of control of minor importance are also operating to some extent to keep the species in check. In barn lots, chickens have been observed to destroy the females which drop to the ground after becoming filled with blood. Some wild birds are known to feed upon various species of ticks, and in one instance, at least, they have been observed to destroy the engorged females of the spotted-fever tick. Certain species of ants are also thought to be important enemies of the pest, particularly when the ticks are in the immature stages.

Owing to the fact that the Rocky Mountain spotted-fever tick is primarily a northern form, and therefore accustomed to severe cold, it is doubtful whether severe winters are of much importance in its destruction. This is particularly true where there is an abundance of protection provided by brush and litter on the ground.

SUMMARY OF LIFE HISTORY OF THE SPOTTED-FEVER TICK.

As is the case with nearly all species of ticks, this one passes through four distinct stages, namely, the egg, the larva or seed tick, the nymph, and the adult.

THE EGG AND LARVA.

The eggs (Pl. II, fig. 5) are small, ovoid, brownish objects, about one thirty-eighth of an inch long. These hatch into minute, light brown, active six-legged creatures known as larvæ or seed ticks. (Pl. III, fig. 2.) Before further development takes place it is necessary for these seed ticks to feed upon the blood of some animal. They usually attach to small mammals, such as ground squirrels, and become filled with blood in from 3 to 8 days. They then drop off the host and find a convenient protected place in which to continue their development. Before engorging the seed tick measures about one thirty-seventh of an inch in length, but during feeding the body is considerably distended, so that it measures about one-eighteenth of an inch in length by one thirty-first of an inch in width when engorgement is complete. The color of the larvæ when engorged is slate-gray. Activity is greatly reduced on account of the weight of the blood imbibed.

THE NYMPH.

After a resting period of from 6 to 21 days the skin is shed from the body of the engorged seed tick and an active eight-legged nymph appears. The extra pair of legs is gained during the resting stage. This character is sufficient to distinguish the nymphs from the preceding or larval stage. In this stage it is necessary for the young tick again to find a host and fill with blood. This feeding period requires from 3 to 9 days. When engorgement is complete (see Pl. III, figs. 3, 4), the nymphs measure about one-sixth of an inch in length, while before engorgement the length is usually about one-seventeenth of an inch. The engorged nymphs are bluish gray in color and not very active.

THE ADULT.

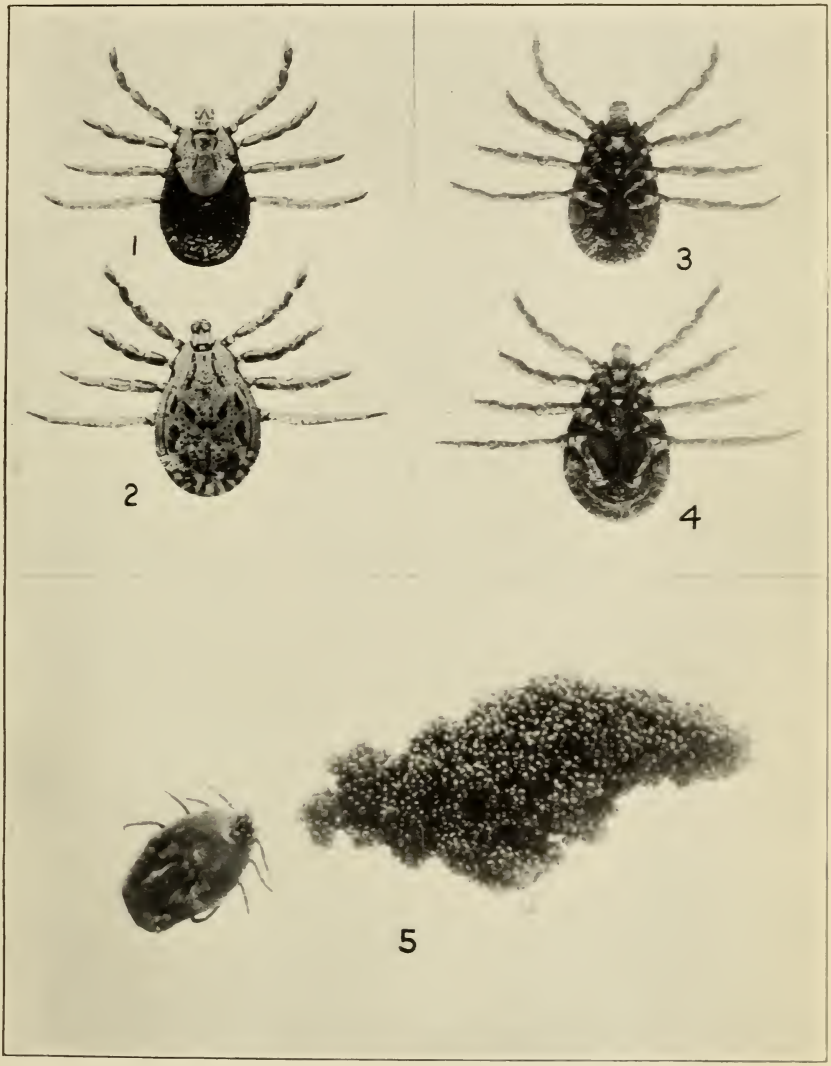
As in the case of the engorged larvæ, the nymphs, after dropping, seek a protected place in which to transform, and there become completely inactive. This resting stage requires a longer period than the preceding. During this time the sexual organs of the ticks develop. When the skins are shed the ticks appear as mature males and females. Shortly before the molting of the nymphs the light-colored shields on the back of the adult ticks can be seen through the thin skins which are soon to be shed. After the mature ticks escape from the nymphal skins they are rather soft and comparatively

inactive. They soon become dried out and the external structures become thoroughly hardened. The color pattern becomes more pronounced and activity increases. This is the stage in which the ticks are ordinarily observed in the spring months. The males (Pl. II, figs. 2, 4) and females (Pl. II, figs. 1, 3) are nearly the same size, but the former have a hard plate or shield covering the entire back. Upon this shield is a somewhat complicated pattern formed by white bands or stripes. In the female the shield is much smaller, covering only the anterior portion of the body. Almost its entire surface is covered with white. The portion of the body of the female behind the shield is rather soft and elastic. It is usually somewhat wrinkled and of a dark reddish-brown color. In this stage, as well as in the preceding, the ticks have eight legs, but the white markings on the backs of both sexes and the presence of a small genital opening on the underside near the "heads" of the ticks serve to distinguish them readily from the other stages. Of course the size of the adult ticks is considerably greater than that of either of the immature stages. Prior to feeding they usually measure about one-sixth of an inch in length by one-tenth of an inch in width.

Before reproduction can begin it is necessary for both the males and females to feed upon the blood of some animal. They usually attach to the large domestic animals, and after feeding about 4 days or more the males start in search of mates. Fertilization takes place on the host, and in from 8 to 14 days after attachment the females, having become filled with blood, drop from the host and seek a protected place in which to deposit their eggs. During the course of feeding the portion of the body of the female behind the shield is greatly distended, so that the specimens now measure about one-half inch long by one-third inch wide by one-fourth inch thick. On account of the enormous distention of the back part of the body of the female, the legs and head are rendered inconspicuous. A close examination, however, will show the white shield on the back just behind the "head." When the females are filled with blood the back part of the body is usually a bluish-gray color. Although the males imbibe a certain amount of blood when attached to an animal they never increase greatly in size as do the females.

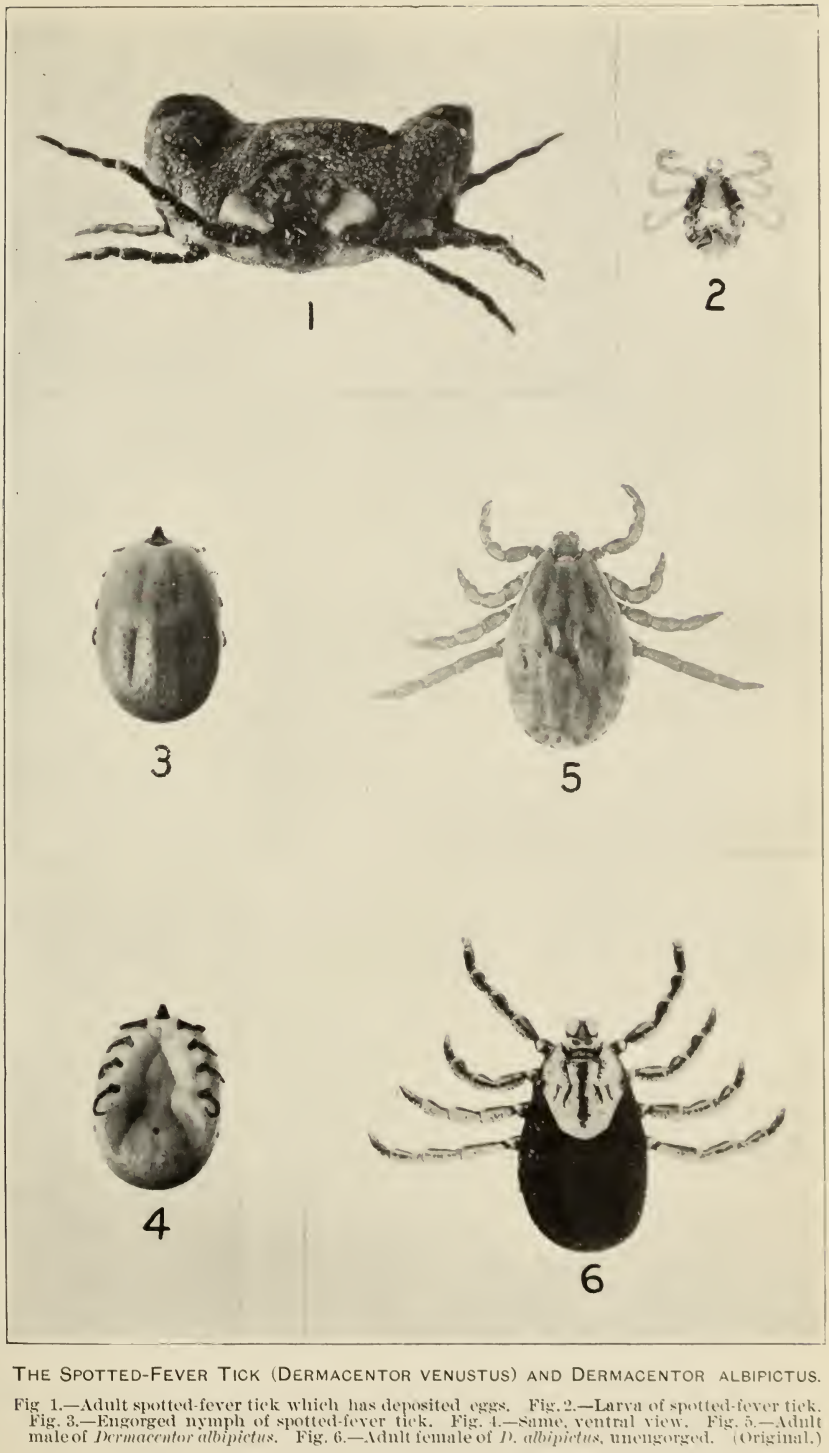
The females always drop from the host animal before beginning the deposition of eggs. Deposition continues for about 30 days, during which time several thousand eggs are deposited. (See Pl. II, fig. 5.) During the process of deposition the female gradually shrinks in size. When all of the eggs are expelled the tick is much shriveled (Pl. III, fig. 1) and has changed in color to a mottled yellowish. She dies within a few days after the last eggs are deposited.

While depositing her eggs the female remains in the same place, so that all of the eggs are in one large mass. The eggs hatch into seed ticks in from 16 to 51 days and the life cycle is again repeated.



THE ROCKY MOUNTAIN SPOTTED-FEVER TICK (DERMACENTOR VENUSTUS).

Fig. 1.—Adult female, unengorged, dorsal view. Fig. 2.—Adult male, dorsal view. Fig. 3.—Adult female, unengorged, ventral view. Fig. 4.—Adult male, ventral view. Fig. 5.—Adult female in act of depositing eggs. (Original.)



THE SPOTTED-FEVER TICK (DERMACENTOR VENUSTUS) AND DERMACENTOR ALBIPICTUS.

Fig. 1.—Adult spotted-fever tick which has deposited eggs. Fig. 2.—Larva of spotted-fever tick. Fig. 3.—Engorged nymph of spotted-fever tick. Fig. 4.—Same, ventral view. Fig. 5.—Adult male of *Dermacentor albipictus*. Fig. 6.—Adult female of *D. albipictus*, unengorged. (Original.)

SEASONAL HISTORY AND HABITS.

For convenience in tracing the life cycle of the Rocky Mountain spotted-fever tick we will begin with the appearance of the flat or unengorged females and males which appear with the first warm days of spring. It should be remembered that these ticks have remained dormant throughout the winter months. When they are rendered active during the warm spring days they are immediately ready to attach to an animal and engorge. Some of these ticks pass the winter in places where they are not readily reached by the warmth of the sun. Such specimens become active later than others. Emergence from winter quarters is therefore gradual, usually extending over a period of a few months, beginning about the 1st of March.

The time of the beginning of activity in the spring is also dependent to a considerable extent upon the relative earliness of the season and upon the locality. In lesser altitudes, and at the southern limit of the range of the species, activity may begin as early as the middle of February, while in the Bitter Root Valley it is probable that the ticks seldom become active in numbers before nearly the middle of March.

After leaving their winter quarters the adult ticks begin crawling about and usually ascend brush to await a host. They may crawl upon trees or other objects so as to get several feet above the ground.

In all ticks the anterior legs have well-developed sense organs located near their tips. These front legs are used as feelers. When the tick is disturbed it immediately begins to wave them in an endeavor to catch any passing object.

Having found a host, the ticks crawl about upon it until a suitable place for attachment is found. On cattle they are usually found in numbers on the dewlap, between the fore and hind legs, and along the belly. On horses they are commonly found between the legs and sometimes in the mane. They may, however, attach to any part of the host.

Attachment to the host is accomplished by means of a spiny beak, which has an opening in the end through which the blood of the animal is drawn. In from 4 to 8 days after attaching the males begin searching for mates. In order to fertilize the females they crawl beneath them, and after mating usually attach to the animal immediately under their mates. When the females have become one-half engorged the blood is rapidly imbibed, and complete engorgement is reached in a very short time, after which they loosen their hold and drop to the ground. Table I shows the time required for the engorgement of females on different hosts and during different times of the year.

TABLE I.—*Time required for engorgement of females of Dermacentor venustus at Dallas, Tex.*

Adults attached.		Dates of dropping as engorged females.		Period of engorgement.
Date.	Host.	First.	Last.	
				Days.
May 15, 1908	Ox	May 23	June 1	8–17
Mar. 19, 1910	Guinea pig	Mar. 28	Mar. 28	9
Apr. 1, 1910	Ox	Apr. 12	Apr. 13	11–12
May 4, 1910	Ox	May 12	May 17	8–13
Mar. 29, 1911	Ox	Apr. 7	Apr. 12	9–14
May 29, 1911[1]	Goat	June 3	June 15	5–17

[1] The specimens in this lot were fertilized and slightly engorged when applied.

After the dropping of the females the males usually remain on the host for some time. We have found that they crawl about over the animal, reattaching in different places and fertilizing a number of different females after one infestation of females has become engorged and dropped from the host.

Immediately after leaving the host engorged females endeavor to find some protected place in which to deposit their eggs. As has been stated, deposition may begin as soon as the seventh day after dropping, and all of the eggs, which usually number about 4,000, are deposited within 30 days. During the process of egg laying the female gradually shrinks in size and death takes place within a few days after all of the eggs have been laid. The length of time before the beginning of egg laying depends largely upon the temperature. During cool weather a period of 41 days has been known to pass after dropping before the first eggs were deposited.

The development of the seed tick begins within the egg as soon as it is deposited. After the embryonic tick has grown for about two weeks, a small white spot appears on one side of the egg. The appearance of this spot enables one to determine whether the eggs will hatch. The time required for incubation is largely dependent upon temperature conditions. In the Bitter Root Valley Mr. W. V. King has determined that this period ranges from 34 to 51 days, the longer period occurring in the early spring months. At Dallas, Tex., we have observed eggs to hatch as early as 15 days after they were deposited, the longest incubation period observed in that locality being 41 days. After the small seed ticks hatch from the eggs they usually remain clustered upon the eggshells for a few days and then crawl upon any object in their immediate vicinity to await a host. In this stage also the front legs are used as feelers, and when an animal comes into contact with the seed ticks, these immediately catch hold. Naturally during the larval stage, as well as during the adult stage, large numbers of the ticks starve before finding a suitable host upon which to engorge. The larvæ die much sooner from starvation than do the other stages of the tick.

During the summer months we have found that all of the seed ticks hatching from a mass of eggs usually die within one month after the first eggs hatch. In one instance a period of 117 days elapsed between the beginning of hatching of the eggs and the death of the last seed tick. This is the greatest longevity which we have observed.

Table II indicates the variations in the time required for the beginning of egg laying, incubation of the eggs, and length of time required for the starvation of the seed ticks:

TABLE II.—*Time required for beginning of deposition of eggs, hatching, and starvation of seed ticks of Dermacentor venustus.*

Date engorged female dropped or was picked from host.	Date first eggs were deposited	Period from dropping of female to beginning of deposition.	Date hatching of eggs began.	Period from beginning of deposition to beginning of hatching.	Date all seed ticks were dead.	Period from beginning of hatching to death of last seed tick.	Mean daily temperature during incubation.
		Days.		*Days.*		*Days.*	°*F.*
June 11, 1909	June 27, 1909	16	July 15, 1909	18	Sept. 5	52	91.8
Mar. 28, 1910	Apr. 7, 1910	10	May 10, 1910	33	July 25	76	70.49
Apr. 2, 1910[1]	May 13, 1910	41	July 3, 1910	51	Aug. 1	30	.....
Apr. 7, 1910	Apr. 17, 1910	10	May 19, 1910	32	July 19	61	74.6
Apr. 13, 1910	Apr. 20, 1910	7	May 25, 1910	35	Aug. 15	82	71.78
Apr. 26, 1910	May 2, 1910	6	May 31, 1910	29	July 30	60	71.63
May 1, 1910[1]	May 19, 1910	18	July 9, 1910	51	Sept. 3	56	.....
May 14, 1910	May 23, 1910	9	June 12, 1910	20	Aug. 31	80	79.64
May — 1910[1]	.....do.....	.....	July 9, 1910	47	Nov. 3	117	.....
June 4, 1910	June 13, 1910	9	June 29, 1910	16	Sept. 29	92	84.37
June 4, 1910[1]	June 17, 1910	13	July 21, 1910	34	Aug. 11	21	.....
July 16, 1910	July 25, 1910	9	Before Aug. 10, 1910	16	Sept. 30	51	84.59

[1] These records were made in the Bitter Root Valley in Montana; all others were made at Dallas, Tex.

Those larvæ which succeed in finding an animal upon which to engorge usually attach about the head and ears of the host, become filled with blood, and drop from the animal between the third and eighth days. In nature the larvæ feed almost entirely upon the small wild mammals, although experimentally they have been forced to engorge upon cattle. As has been stated, the larvæ after becoming engorged drop from the animal, find a protected place, shed their skins, and become active eight-legged creatures known as nymphs. These nymphs emerge from the quiescent seed-tick stage from about the middle of July to the beginning of cold weather. Some of those transforming during the summer find hosts, become engorged, and drop for molting. A few of these probably molt to adults before cold weather begins and hibernation takes place in the adult stage. These few individuals are the only ones which complete their life cycle in a single season. It should be emphasized that these nymphs, as well as the seed ticks, feed almost exclusively on small wild mammals. Tables III and IV show the length of the engorgement and molting periods of larvæ and nymphs.

TABLE III.—*Time required for molting of seed ticks and nymphs of Dermacentor venustus.*

Seed ticks dropped engorged.		Date seed ticks molted.		Period from dropping to molting.	Nymphs dropped engorged.		Date nymphs molted.		Period from dropping to molting.
Date.	Number.	First.	Last.		Date.	Number.	First.	Last.	
1908.		1908.	1908.	*Days.*	1908.		1908.	1908.	*Days.*
Apr. 5	23	Apr. 20	Apr. 24	15–19	Aug. 6	17	Aug. 20	Aug. 22	14– 16
					1909.		1909.	1909.	
May 17	15	May 27	May 30	10–13	Sept. 15	5	Aug. 6	Aug. 7	21– 22
1909.		1909.	1909.					1910.	
Aug. 6	7	Aug. 13	Aug. 16	7–10	Oct. 3	3	Oct. 21	Mar. 22	18–170
					1910.		1910.		
Sept. 1	56	Sept. 7	Sept. 10	6– 9	Mar. 23	2	May 4	May 23	42– 61
1910.		1910.	1910.						
July 4[1]	Many.	July 18	July 25	14–21	Apr. 14	13	May 24	May 30	40– 46
July 8[1]	Many.	July 19	...do.....	11–17	July 21	1	Aug. 1	Aug. 1	11
July 22[1]	Many.	Aug. 8	Aug. 11	17–20	Aug. 1	6	Aug. 14	Aug. 16	13– 15
1911.		1911.	1911.						
May 22	110	May 30	June 2	8–11	Aug. 19	12	Aug. 31	Sept. 4	12– 16

[1] These records were made in the Bitter Root Valley, Mont.; all others were made at Dallas, Tex.

TABLE IV.—*Time required for engorgement of seed ticks and nymphs of Dermacentor venustus.*

Seed ticks applied.		Date of dropping as engorged seed ticks.		Period of engorgement.	Nymphs applied.		Date of dropping as engorged nymphs.		Period of engorgement.
Date.	Host.	First.	Last.		Date.	Host.	First.	Last.	
1908.		1908.	1908.	*Days.*	1908.		1908.	1908.	*Days.*
Apr. 2	Ox.....	Apr. 5	Apr. 10	3–8	Apr. 1	Ox.....	Apr. 5	Apr. 8	4–7
					1909.		1909.	1909.	
July 12	.....do	July 15	July 18	3–6	Aug. 13	Guinea pig.	Aug. 17	Aug. 18	4–5
1909.		1909.	1909.						
July 28	Guinea pig.	Aug. 2	Aug. 4	5–7	Sept. 10	Rabbit.....	Sept. 14	Sept. 15	4–5
					1910.		1910.	1910.	
Aug. 2	Rabbit.....	Aug. 7	Aug. 7	5	May 24	Bovine.....	May 30	May 30	6
Aug. 27	Guinea pig.	Aug. 29	Sept. 3	2–7	Aug. 13	Rabbit.....	Aug. 18	Aug. 20	5–7
1910.		1910.	1910.						
July 19[1]	Ground squirrel.	July 22	July 23	3–4	Aug. 19	Rabbit.....	Aug. 23	Aug. 28	4–9
1911.		1911.	1911.						
May 18	Guinea pig.	May 21	May 24	3–6	Aug. 17[2]	Ground squirrel.	Aug. 22	Aug. 27	5–9

[1] This record was made by W. V. King in the Bitter Root Valley, Mont. Dropping probably began on July 21, or the second day after application.

[2] This record was made in the Bitter Root Valley, Mont. Records not referred to in footnotes were made at Dallas, Tex.

Those larvæ which hatch from eggs deposited by females which do not find hosts until late in the spring become engorged during July and August and do not molt to nymphs until shortly before winter. It is thus necessary for the nymphs which appear late in the summer to pass the winter in that stage. These nymphs appear in the spring shortly after the emergence of the adult ticks; that is, shortly after the middle of March. They continue to emerge from

their winter quarters for some time, the last individuals not securing hosts upon which to engorge until early in July. These individuals molt to adults during the latter part of the summer, and the resulting adults pass the winter before feeding.

In contrast to the short length of life as exhibited by the larvæ, we find the vitality of the nymphs and adults to be remarkably great. It has been determined that adults collected on vegetation during the spring months may survive for a period of 413 days without food. These individuals undoubtedly passed the winter in the adult stage, and therefore the total length of life must have been approximately one and two-thirds years. However, in nature the great majority of the ticks with a vitality equal to this lot would probably find hosts and become engorged. Unfed nymphs have been found to survive a period of more than 300 days. It is thus possible for ticks which pass the winter in the nymphal stage to live until at least July 15 of the following year. Under natural conditions this longevity is probably even greater.

The following is a summary of the life cycle of the tick: The winter is passed as flat or unengorged males and females and as unengorged nymphs. The former are present from about March 15 to July 15, during which time they find hosts and become engorged. It is during this period that the pest attacks man and communicates to him the germs of Rocky Mountain spotted fever. The eggs deposited by the females which find hosts early in the spring hatch into larvæ, which may develop into adults by the first or middle of September. The offspring of the females which become engorged late in the season succeed in developing only as far as the unengorged nymphal stage before cold weather begins. The overwintered nymphs begin appearing from their winter quarters during the latter part of March. They are to be found upon small wild mammals from that time until about the middle of July, at which time the nymphs which have developed from the females engorged during that spring are also present. Overwintered nymphs transform to adults during the summer and fall, and the majority of these adults pass the winter in the unfed condition. A few of the first nymphs to find hosts early in the spring may molt to adults sufficiently early in the summer to allow the adults to become engorged, deposit eggs, and the transformation to proceed to the unfed nymphal stage by the approach of cold weather, thus completing a life cycle in one year. However, the individuals which proceed with development beyond the unengorged adult stage during the same season must be very exceptional. When the mean temperature is low during the spring and early summer it is almost certain that none of the individuals which have passed the winter as unengorged nymphs develop further than unengorged adults during that season.

It has been observed that even though the adults which transform from overwintered nymphs are kept confined with the host animal during the summer or fall following their maturity, they show no marked desire to feed, usually endeavoring to crawl away and become quiet. Thus the habit of the adults of attaching to hosts in the spring appears to be so well established that they can scarcely be induced to attach to a host after midsummer.

From the foregoing statements it is evident that although a few of the ticks may complete their life cycle—that is, the transformation from unengorged adults to unengorged adults of the next generation, or from unengorged nymphs to unengorged nymphs of the next generation—during one season, the majority require two years for this cycle. Should overwintered nymphs not find hosts until late in the season and thus not become adult until the approach of winter, the resulting adults, if unable to find hosts, may survive until the second spring following. Ticks which pass the winter in the adult stage may survive until the second spring following, then engorge and produce offspring which develop to nymphs the second summer, pass the winter in the nymphal stage, and complete development to unengorged adults during the third season. Thus it is apparent that under certain conditions three years might be required for the completion of the life cycle. This would necessitate the destruction of the adult ticks during three successive seasons in order to eradicate the species.

Figure 2 shows several of the ways in which development may proceed.

THE HOST ANIMALS OF THE SPOTTED-FEVER TICK.

The investigations conducted by Dr. Ricketts indicated that the Rocky Mountain spotted fever tick is restricted in regard to its host relations. Our investigation has shown that this restriction of certain stages of the tick to certain classes of animals is very well marked. *The examination during three seasons of nearly 800 wild mammals which are inhabitants of the Bitter Root Valley and numerous observations made elsewhere have shown that, with few exceptions, only the immature stages of the tick are to be found on this class of hosts. On the other hand, the large domestic animals are the principal hosts of the adult ticks, and the immature stages are rarely, if ever, found upon them.* This restriction of the adult stage to the larger mammals, now a firmly fixed habit of the tick, undoubtedly arose from the fact that the adult ticks are so large that they can be easily removed by the smaller mammals. As will be pointed out in the discussion of remedial measures, this habit of the Rocky Mountain spotted-fever tick may be taken advantage of in the control or eradication of the species.

FIG. 2.—*Diagram showing the possible seasonal history of the Rocky Mountain spotted-fever tick.*

Overwintered individuals.	Unengorged adults.	Some fail to engorge the following season.	But engorge and deposit eggs the second spring.	These develop to unengorged nymphs that season and pass the winter in that stage.	These engorge and molt to adults the following summer.	These require three years, to complete the life cycle.
		Some become engorged early in spring.	Eggs deposited by these hatch in early summer.	Some seed ticks engorge and molt to nymphs in midsummer.	A few of these nymphs may engorge and molt to adults in the fall. These pass the winter as unengorged adults.	These require but one year to complete the life cycle from unengorged adults to unengorged adults.
					The majority do not feed but pass the winter as unengorged nymphs.	
				Others engorge and molt to nymphs in late summer.	These pass the winter as unengorged nymphs.	These engorge and molt the following spring, thus requiring two years to complete the life cycle.
		Others become engorged in late spring and early summer.	Eggs deposited by these hatch in mid or late summer.	Some seed ticks engorge and molt to nymphs in late summer or early fall.	These pass the winter as unengorged nymphs or a few may engorge and pass the winter as engorged nymphs.	
				A very few remain unengorged or engorge in the fall.	These enter the winter as unengorged or engorged larvæ and die during the winter.	
	Unengorged nymphs.	Some become engorged in spring.	These molt to adults in spring or early summer.	A few may engorge in summer and deposit eggs.	A few of the earlier hatch and the larvæ engorge and molt to nymphs which pass the winter in this stage.	These complete the life cycle from unengorged nymph to unengorged nymph in one year.
					The later-deposited eggs either fail to hatch or die during winter as seed ticks.	
						Some of these engorge, deposit eggs, and the resulting seed ticks transform to nymphs the following year, thus requiring two years to complete the life cycle.
		Others become engorged in summer.	These molt to adults in late summer or fall.	Remain quiet during the rest of the summer.	And pass the winter as unengorged adults.	Others fail to find hosts and do not engorge until the second spring, development proceeding that season to unengorged nymphs, thus requiring three years to complete the life cycle.

Among the domestic animals which act as hosts for the adult stage of the tick, horses and cattle are of prime importance. A number of collections indicates that sheep are frequently attacked, but with smaller numbers of ticks. Dogs have also been found to harbor this species, but in limited numbers only. Among nearly 100 collections of ticks made on dogs in the territory in which this species occurs only 12 lots of this tick have been obtained. Only 2 of these 12 lots contained females which were sufficiently engorged to deposit eggs. This indicates that the majority of the ticks are scratched off by the dogs before becoming fully filled with blood. Mules and asses have also been found infested with this species, and in two instances collections have been made upon hogs. It is not likely that the latter host is of much importance, particularly when the animals are kept confined in pens and thus not exposed to the ticks.

Among the wild animals which act as hosts for the adults, the mountain goat harbors by far the greatest number. In addition to specimens of the adults, nymphs have also been found upon them. The brown bear and coyote have been found to be infested with considerable numbers of spotted-fever ticks, some of the specimens being sufficiently engorged to deposit eggs. The snowshoe rabbit and jack rabbit have occasionally been observed to be infested with limited numbers of adults, but on neither of these hosts have engorged specimens been captured. The woodchuck has also been found to act as a host for the adult stage. In only one instance, however, were specimens taken upon this host, although 51 of the animals were examined during the investigation.

The Columbian ground squirrel is undoubtedly by far the most important host of the immature stages of this tick in the Bitter Root Valley. In other parts of the Western States, where this species of ground squirrel does not occur, related species have been found to act as hosts for both of the immature stages of this tick. In the Bitter Root Valley 65 per cent of the 341 Columbian ground squirrels examined were found to be infested with immature ticks of the genus Dermacentor. Owing to the fact that very large numbers of the immature stages of ticks belonging to the genus Dermacentor collected in the Bitter Root Valley were reared to adult and all found to be the Rocky Mountain spotted-fever tick, we can say with practical certainty that this is the only species of this genus which occurs on the small mammals in that locality. Second in importance as a host of the immature stages of this tick in the Bitter Root Valley is the yellow-bellied chipmunk. Thirty-seven per cent of 131 of these mammals which were examined were found to be infested with seed ticks and nymphs. The pine squirrel is also of much importance, as 29 per cent of the 181 mammals examined were in-

TABLE V.—*Wild mammals examined in the Bitter Root Valley during 1910–11, with number and stages of Dermacentor venustus found thereon.*

Common names.	Scientific names.	Number of animals examined.	Number of animals with spotted-fever ticks.	Per cent of animals examined which were infested with spotted-fever ticks.	Number of spotted-fever ticks found.					State of engorgement of adult females.
					Seed ticks.	Nymphs.	Adults.	Total.	Per animal.	
Columbian ground squirrel	Citellus columbianus	341	240	64.5	841	1,234	0	2,075	6.09	
Yellow-bellied chipmunk	Eutamias b. luteiventris	131	49	37.4	539	60	0	599	4.57	
Pine squirrel	Sciurus h. richardsoni	181	53	29.3	503+	83	0	586+	3.24	
Woodchuck	Marmota flaviventer	47	26	55.3	9	379	2 or 3	390	8.29	Slight.
Side-striped ground squirrel	Callospermophilus l. cinerascens.	48	25	52.1	31	100	0	131	2.72	
Wood rat	Neotoma cinerea	16	11	68.8	8	12	0	20	1.25	
Snowshoe rabbit	Lepus bairdi	4	3	75.0	0	3	[1] 3	6	1.50	One-seventh.
Cottontail rabbit	Sylvilagus nuttalli	16	5	31.3	11	4	0	15	.94	
White-footed mouse	Peromyscus m. artemisiæ	50	[2] 6	12.0	16	4	0	20	.40	
White-bellied chipmunk	Eutamias q. umbrinus	58	5	8.6	44	4	0	48	.83	
Large meadow mouse	Microtus modestus	32	[2] 6	18.8	0	7	0	7	.22	
Jumping mouse	Zapus princeps	13	[2] 1	7.7	1	0	0	1	.08	
Pika or rock rabbit	Ochotona princeps	28	1	3.6	0	1	0	1	.04	
Pocket gopher	Thomomys fuscus	12	1	8.3	1	0	0	1	.08	
Longtailed meadow mouse	Microtus mordax	5	[2] 0	0	0	0	0	0	0	
Gray meadow mouse	Microtus n. canescens	2	[2] 0	0	0	0	0	0	0	
Red-backed mouse	Evotomys idahoensis	4	[2] 0	0	0	0	0	0	0	
Flying squirrel	Sciuropterus alpinus	3	0	0	0	0	0	0	0	
Shrews	Sorex sp	10	[2] 0	0	0	0	0	0	0	
Mountain goat	Oreamnos montanus	3	3	100.0	0	[3]	300+	300+	100.0+	Unengorged to fully engorged.
Brown bear	Ursus americanus	1	1	100.0	0	0	[4] 13	13	13.0	Slightly to one-fourth.
Coyote	Canis lestes	2	2	100.0	0	0	[5] 33	33	16.5	Unengorged to slightly.
Mule deer	Odocoileus hemionus	6	0	0	0	0	0	0	0	
White-tailed deer	Odocoileus leucurus	2	0	0	0	0	0	0	0	
Elk	Cervus canadensis	1	0	0	0	0	0	0	0	
Badger	Taxidea taxus	3	1	33.3	0	0	[6] 1	1	.3	
Weasel	Putorius arizonensis	5	0	0	0	0	0	0	0	
Muskrat	Fiber zibethicus	3	0	0	0	0	0	0	0	
Bats	Vespertilionidæ	7	0	0	0	0	0	0	0	

[1] 2 males, 1 female.
[2] Several dead before being examined. Some ticks may have left the animals.
[3] A few. These may have been nymphs of D. albipictus. They were lost before being examined.
[4] 4 males, 9 females.
[5] 15 males, 18 females. A few others escaped.
[6] 1 male (dead).

fested. Among the other mammals which are of considerable importance as hosts of the immature stages are the large chipmunk, the woodchuck, snowshoe rabbit, rock squirrel, wood rat, white-footed mouse, and meadow mouse.

Our knowledge of the tick hosts in the valley was greatly increased by the cooperation of the Biological Survey of this department. Messrs. Howell and Birdseye, of the Survey, were located at the camp laboratory and made extensive collections during 1910. This work was continued in 1911 by Mr. Birdseye. Table V furnishes a list of the wild mammal hosts of this tick. It includes all the records of the Biological Survey,[1] as well as a number made independently by Mr. King, of the Bureau of Entomology. The mammals are listed in the table according to their relative importance as hosts of the immature stages. It is especially worthy of note that among the wild mammals which act as hosts for the adult stage the mountain goat and brown bear are the only ones which were found to have ticks upon them which were engorged sufficiently to deposit eggs.

One hundred specimens of the birds commonly found in the valley were examined and found to be free from ticks.

TABLE VI.—*Host animals on which Dermacentor venustus in the adult stage has been found.*

ON DOMESTIC ANIMALS AND MAN.

Common names.	Scientific names.	Approximate number of hosts examined.	Approximate number of ticks collected.			State of engorgement of females.
			Males.	Females.	Total.	
Ox	Bos taurus	200	2,000	2,000	4,000	Unengorged to fully.
Horse	Equus caballus	800	2,500	2,500	5,000	Do.
Ass	Equus asinus	5	9	5	14	Do.
Mule	Equus asinus×caballus.	9	14	17	31	Do.
Sheep	Ovis aries	75	22	32	54	Unengorged to one-half.
Dog	Canis familiaris	100	18	20	38	Unengorged to three-fourths.
Goat	Capra hircus	5	0	4	4	Unengorged to slightly.
Hog	Sus scrofa	10	2	4	6	Unengorged to one-third.
Man	Homo sapiens	900	400	400	800	Unengorged to one-fourth.
Domestic cat	Felis domesticus	1	1	0	1	Unattached.

ON WILD ANIMALS.

Mountain goat	Oreamnos montanus.	3	150	150	300	Unengorged to fully.
Coyote	Canis lestes	1	15	16	31	Unengorged to slightly.
Brown bear	Ursus americanus	1	4	9	13	Slightly to one-fourth.
Jackrabbit	Lepus sp	15	3	6	9	Slightly to one-sixth.
Woodchuck	Marmota flaviventer.	51	2 or 3	2 or 3	5	Slightly.
Snowshoe rabbit	Lepus bairdi	4	2	1	3	One-seventh engorged.
Wild cat	Lynx uinta	1	1	0	1	
Badger	Taxidea taxus	4	[2] 1	0	1	

[1] See United States Department of Agriculture, Biological Survey, Cir. No. 82.
[2] Dead.

OTHER SPECIES OF TICKS FOUND IN REGIONS WHERE ROCKY MOUNTAIN SPOTTED FEVER OCCURS.

Five species of ticks other than *Dermacentor venustus* have been found to occur more or less commonly in the Bitter Root Valley of Montana. These are: *Dermacentor albipictus* Pack. (Pl. III, figs. 5, 6), *Ixodes angustus* Neum., *Ixodes texanus* Banks, *Ixodes kingi* Bishopp, and *Haemaphysalis leporis-palustris* Pack. On account of the host relations of these ticks it is impossible for them to play any important part in the dissemination of Rocky Mountain spotted fever. *Dermacentor albipictus* has been found to occur on practically no other animals than horses, cattle, and mountain goats. It never attacks man. Neither one of the three species of Ixodes has been found to occur on man, and they very seldom attack the domestic animals, being confined to certain of the small wild mammals. The last-named species confines its attack exclusively to rabbits with the exception of the immature stages, which are occasionally found upon birds.

In parts of Idaho, Oregon, Nevada, and Utah, the rabbit Dermacentor (*Dermacentor parumapertus marginatus* Banks) is found quite commonly. Like the other common rabbit tick this species confines its attack exclusively to that host.

SPECIES OF TICKS WHICH MIGHT PLAY AN IMPORTANT PART IN THE DISSEMINATION OF THE DISEASE SHOULD IT BE INTRODUCED INTO NEW REGIONS.

Since it has been shown by Dr. Maver, of the University of Chicago, that Rocky Mountain spotted fever may be transmitted by several different species of ticks, the importance of limiting the disease-infested area to the territory now covered is strongly emphasized.

A closely related species, namely, *Dermacentor occidentalis* Neum., has been found to occur throughout western California and southwestern Oregon. At present the range of this species does not overlap that of the Rocky Mountain spotted-fever tick. On account of the fact that this species is an important pest of man, should the disease become introduced into the territory where it occurs its dissemination would be certain. In the eastern and southern United States several species occur which commonly attack man. Nearly all of these have host relations very similar to that of the Rocky Mountain spotted-fever tick, and therefore the disease might readily be transmitted from animal to animal and from animal to man by any of these species. The following species would probably be of principal importance in the Southern and Eastern States: The lone-star tick (*Amblyomma americanum* L.); the American dog tick (*Dermacentor variabilis* Say), and the gulf-coast tick (*Amblyomma maculatum* Koch). In the extreme southern portions of

Texas and New Mexico the Cayenne tick (*Amblyomma cajennense* Fab.), is a common pest of man.

PRACTICAL CONTROL OR ERADICATION OF THE SPOTTED-FEVER TICK.

In 1909 Dr. Ricketts suggested, in a general way, a plan for the practical eradication of spotted fever from the Bitter Root Valley by a campaign against the ticks. It became evident to Dr. Ricketts as the result of his work on spotted fever that the only method of controlling the disease was by destroying the natural agency of transmission. The work of the Bureau of Entomology in cooperation with the Montana Agricultural College and the Biological Survey in obtaining exact information about the life history and hosts of the tick has served to elaborate upon the suggestions made by Dr. Ricketts and to make it possible to lay down definite plans that should be followed.

It has been pointed out in this bulletin that the plan of eradication, which is dependent upon a knowledge of the tick, is entirely feasible and economical. The question now is whether the loss of 25 or more human lives per year in the Bitter Root Valley, the onus placed upon the development of the valley by the presence of spotted fever, and the danger of the spread of the virulent strain of spotted fever to other regions are not of sufficient importance to justify the small cost that the work will entail. A considerable portion of this cost would be offset by the improved condition of the live stock which would result from the destruction of the ticks as well as of certain other parasites.

CONDITIONS FAVORING CONTROL.

It will be understood from the discussion of the life history of the spotted-fever tick that several facts will assist greatly in an attack against it. Among these are the following:

(1) The vast majority of fever ticks which develop to the adult stage in the Bitter Root Valley do so upon horses and cattle, although small numbers develop upon sheep and a very few upon dogs. The only other domestic animal of any importance in the Bitter Root Valley is the hog. Although no fever ticks have ever been found upon hogs in the valley the adult form was taken in considerable numbers on that host on one occasion in Wyoming. It is therefore evident that under some conditions the hog is to be looked upon as an agency for the breeding of the ticks. The danger on this score, however, is exceedingly remote on account of the method of management of hogs in the valley. In the first place the number of these animals is not large. In the second place they are not allowed to roam at large but are confined to pens or small inclosures where the chances of their picking up fever ticks are very small. If hogs were

allowed to roam into the brushy land on the edges of the valley they might assume importance, but as the present plan of keeping them confined to areas where, for all practical purposes, ticks do not occur will undoubtedly be continued in the future, it is considered safe to ignore them in a plan of practical eradication.

(2) Aside from the domestic animals the wild species which have been found to carry the tick must be considered. These wild mammals can be divided for the purposes of this discussion into two groups, namely, those small forms which frequent the floor of the valley and extend in some cases to considerable elevations in the mountains, and the larger forms, like the bear, deer, elk, and mountain goat, which are more or less confined to the mountainous walls of the valley, but nevertheless sometimes visit the fields below.

Regarding the small wild mammals found throughout the valley, it was ascertained by examination of very large numbers of specimens that they seldom or never serve as hosts for the adult ticks. The immature forms of the fever tick are frequently to be found upon these mammals, but the *development of the adults is practically restricted to the larger domestic animals.*

Regarding the larger wild mammals it may be said that their numbers are rapidly decreasing. Some of them are practically extinct. The mountain goat, which appears more or less frequently to carry the adult fever tick, never invades the valley proper. In the winter it is to be found upon the lower rocks of the mountain walls, but it moves back to higher elevations as the snow melts. Therefore mountain goats tend rather to remove ticks from the valley than to plant them there. Among the other possible hosts, the two species of deer are rapidly becoming scarce. Moreover, in our investigations no fever ticks have been found attached to deer. The bear, among the wild mammals, is probably the most likely to serve as a host for the fever tick. It can not be considered that this mammal is abundant enough, however, to have any important bearing on the situation. The same is true of the coyote. In fact the number of ticks that could possibly be reared upon all the larger wild hosts would not be sufficient to cause any considerable infestation of the valley. These mammals can not be ignored altogether, but it is safe to consider them as comparatively unimportant. They might be of considerable importance if the project were to exterminate the fever in the valley and surrounding regions absolutely. But the plan here proposed is to reduce the cases of spotted fever to a practically negligible number in the valley. This is feasible and can be accomplished at small cost, while total eradication of the fever ticks in the mountains is not necessary to relieve the situation.

Since it has been pointed out that the larger domestic animals—horses, cattle, sheep, and dogs—are necessary hosts for the propaga-

tion of the fever tick, the problem of control becomes very greatly simplified. The immature stages may be allowed to develop on the small mammals in the valley so long as the adult stage may be destroyed upon the domestic animals which are necessary for its development.

Of course the reduction of the number of rodents in the valley, especially the Columbian ground squirrel, is advisable. These animals are more or less serious agricultural pests. They destroy a considerable amount of produce, and the inhabitants of the valley are in the habit of waging warfare against them. Undoubtedly the damage done is abundantly sufficient to warrant this work. The reduction of the rodents should be encouraged both on general economic principles and because they carry the immature stages of the spotted-fever tick. This line of work may well supplement the main work which must be done with the larger domestic animals, and will undoubtedly hasten the removal of the fever tick from the valley.

In one respect work against the rodents is of more than incidental value. It was found by Dr. Ricketts that five of these animals, namely, the gopher, rock squirrel, woodchuck, chipmunk, and mountain rat, are susceptible to spotted fever, and may serve as the original source of the disease in nature, or, at any rate, furnish a reservoir from which is derived the infection of human beings by the agency of ticks. The main point, however, is to destroy the tick which is necessary for the propagation of the disease, and this can be done by directing the principal efforts against the ticks on the larger animals which are under the control of man.

There are several facts, in addition to the practical restriction of the adult fever tick to the larger domestic animals, which will serve to render a campaign of eradication feasible. One of these is that the adult ticks are to be found on domestic animals or elsewhere during only a part of the year. Efforts toward eradication need not begin before March 1 and there would be no necessity for their continuance far beyond June 15. This is the season when the work can be done most easily and with smallest risk to the stock. A line of attack extending throughout the year is entirely unnecessary. Another favorable factor is the small number of live stock that would have to be treated. This is shown by the table below:

TABLE VII.—*Number of live stock in Bitter Root Valley. (U. S. Census, 1900.)*

	Ravalli County.	Missoula County.
Neat cattle	22,461	13,684
Horses	6,713	4,125
Mules	18	36
Sheep	58,212	4,942

Moreover, in the Bitter Root Valley eradication would not suffer the drawbacks connected with the ownership of large bodies of land by single persons which have attended similar work that has been undertaken in other parts of the country. The total number of farms in Ravalli County, as given in the census of 1900, was 891; their average size 199.4 acres. In Missoula County the same authority gives 615 farms of an average size of 241.6 acres.

An additional advantage will be found in the large proportion of farms in the county which are operated by their owners. Very little difficulty on account of nonresident ownership is to be expected. In Ravalli County 77 per cent of the farms are operated by the owners, and in Missoula County 89.

Aside from the specific factors which would operate to facilitate eradication of the spotted fever tick, others of a general nature may be mentioned, namely, the small size of the valley and its practical inclosure by high mountains, and the public interest in eradication which has already arisen. The Bitter Root Valley lies between high ranges of mountains over which there is practically no travel. The upper end of the valley is also closed by high mountains over which a very inconsiderable amount of traffic takes place. The lower end is narrowed almost to a gorge. Practically all the traffic into or out of the valley goes through this narrow opening at the northern end. The lay of the land gives an isolated region into which infection from the outside would be very unlikely to take place. For all practical purposes the guarding of the lower end for a portion of the year would be sufficient to prevent reinfection in case eradication is undertaken. The soil of the Bitter Root Valley has been found to be exceedingly fertile and especially adapted to certain profitable crops. It is recognized by all intelligent residents that the principal obstacle to the rapid development which has already begun is the occurrence of spotted fever. There is consequently a firmly embedded popular opinion that the destiny of the valley demands the eradication of the fever tick.

We may summarize the more important facts and conditions which would facilitate eradication of the fever tick as follows:

(1) Practical restriction of the adult stage of the tick to the larger domestic animals.

(2) The short season in the spring over which it would be necessary to carry on the principal work of eradication.

(3) The small number of animals that would have to be treated.

(4) The small size of the farms.

(5) The preponderance of resident farm owners.

(6) The isolation of the valley and the existence of effective natural barriers against reinfestation.

(7) A commendable public opinion in favor of removing an important obstacle to development.

IMPORTANCE OF CONTROL THROUGHOUT THE BITTER ROOT VALLEY.

For several reasons it is necessary to carry on this plan of eradication on both sides of the valley. It is known that the fever is very much less prevalent on the east than on the west side. This situation, however, is undoubtedly in part due to the heavier population on the west side and the greater number of live stock. There is every reason to believe that the settlement of the east side, with the inevitable increase in the number of live stock and, consequently, of opportunities for the ticks to breed to maturity, would result in an increased number of cases of spotted fever. That this is not a remote danger is shown by the fact that the development of the east side has already begun and will undoubtedly continue with rapidity. We do not wish to be understood as believing that the comparatively unsettled condition of the east side is the only reason for the scarcity of ticks. There are undoubtedly others. Among these is the greater abundance of rodent hosts for the immature stages of the tick on the west side. This is due primarily to the larger amount of protection in the brush or "slashings," although the settlement of the land and the planting of crops may have tended, by furnishing food, toward the multiplication of the rodents. Soil conditions may also have something to do with the difference.

The main point, however, is that the comparative immunity of the east side is not likely to continue. Destroying the ticks on both sides would cost but little more than on one. It would prevent the reinfestation of the west side. If it were not done, it would be necessary to establish and to maintain a quarantine against live stock on the east side. From every point of view it is wise to conduct a thorough work and clear both sides of the valley at the same time.

METHODS OF DESTROYING TICKS.

The two methods of eradicating ticks which will be found to be adapted to the conditions of the Bitter Root Valley are (1) the dipping of live stock in vats provided for the purpose, and (2) the hand treatment of such animals as can not conveniently be dipped.

In the case of the tick (*Margaropus annulatus* Say) which transmits splenetic fever of cattle, a third method has been found to be of great importance. This is the elimination of the ticks from pastures by "starving" them. This is accomplished by keeping the cattle out. During the warm portions of the year, at least, only a few months time without hosts will result in the death of the cattle ticks. Important differences between the life history of the splenetic-fever tick and that of the spotted-fever tick make that plan entirely impracticable in the case of the latter species. The problem of the splenetic-fever tick is not complicated by the existence of different hosts for the immature and the adult stages. That tick is absolutely depend-

ent upon cattle and remains on its host until mature. The spotted fever tick, however, drops to the ground twice for the purpose of molting and develops through the immature stages upon certain rodents and other animals. In the opinion of the Biological Survey the extermination of these rodents within reasonable time appears to be impracticable because of the necessary expense. The problem is even further complicated by the remarkable ability of the fever ticks to live for long periods without hosts. As shown in the discussion of the longevity of the stages of the spotted fever tick, a period of three years, in which horses and cattle were kept out of the pastures, would be required before eradication could be brought about. This long period renders the so-called starvation plan entirely impracticable.

DIPPING.

Undoubtedly the so-called arsenical dip is the one best adapted for use in the Bitter Root Valley. In fact this dip has practically displaced all others for the destruction of ticks in various parts of the world. Crude oils have been used to a considerable extent in some cases. They are more expensive than the arsenical dip and dangerous to cattle under some conditions. Serious losses have followed the use of heavy oils in dry regions or where it has been necessary to drive the cattle any considerable distance after dipping.

Another advantage that the arsenical dip will be found to have over crude oil for the work in the Bitter Root Valley is that it will not act as a repellent. When cattle are oiled a portion of the oil remains in the hair and upon the skin for several days. This will prevent ticks from attaching. In the case of the arsenical dip, however, there is very little repellent effect. As the object of the work is to kill the ticks rather than to keep them from the animals, the more that can be caused to attach the better.

The formula for the arsenical dip is as follows:

Sodium carbonate (sal soda)	pounds	24
Arsenic trioxid (white arsenic)	do	8
Pine tar	gallons	2
Water to make	do	500

The preparation of the arsenical dip is described in Farmers' Bulletin No. 378, Methods of Exterminating the Texas-fever Tick, prepared by the Bureau of Animal Industry of this department, as follows:

> In preparing the dip, a large caldron or galvanized tank is required for heating the water in which to dissolve the chemicals. Thirty or forty gallons of water should be placed in the caldron or tank and brought to a boil. The sodium carbonate is then added and dissolved by stirring. When this is accomplished, the arsenic is added and dissolved in a similar manner. The fire is then drawn and the pine tar added slowly in a thin stream and thoroughly mixed with the dip by constant stirring. This strong stock solution is diluted to make 500 gallons before using.

The only precautions necessary are to see that live stock are not allowed to drink it and to avoid heating the animals either before or after dipping. The dip can be used repeatedly until it becomes

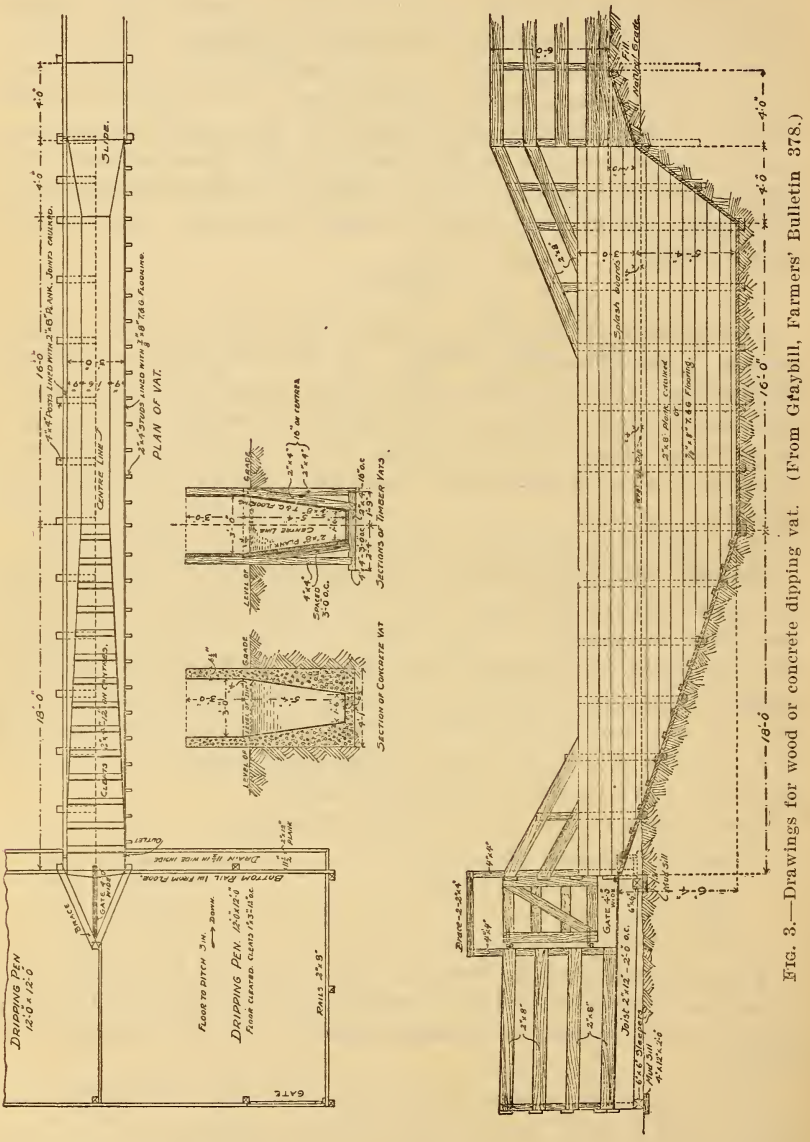


Fig. 3.—Drawings for wood or concrete dipping vat. (From Graybill, Farmers' Bulletin 378.)

befouled by foreign matter. A reasonable estimate of the cost of preparing this dip in the valley is $0.0031 per gallon, or $6.20 for an amount sufficient to fill a vat of 2,000 gallons capacity.

CONSTRUCTION OF VATS.

The specifications for such vats as will be found best adapted to use in Montana are taken from Farmers' Bulletin No. 378, already referred to, as follows:

SPECIFICATIONS AND MATERIALS FOR A DIPPING VAT.

A vat constructed according to the accompanying plans will hold 2,088 gallons when filled to a depth of 5 feet.

Excavation.—Excavate for the vat, as shown by the drawings [fig. 3], to the proper depth. Level the bottom of the pit for the sills. After the vat is completed fill in around it, using the surplus natural grade, and slope the surface away from the vat. Dig the holes required for all posts, etc.

Carpenter work.—The drawings show the vat constructed according to two methods. One method is to make the sides of 4 by 4 inch posts spaced about 3 feet apart and lined with 2 by 8 inch dressed, sized, and bevel-edged plank, using 20-penny spikes to fasten them to the posts and braces. All the joints are to be calked with oakum, well driven in with a calking iron, and pitched. The floor of the vat and the inclines are to be made of 2-inch plank, with joints calked; the exit incline to have 2 by 4 inch cleats spiked to the plank flooring. The slide should have an angle of about 25° and should be covered with No. 16 galvanized iron.

The other method is to build the sides of the vat of 2 by 4 inch posts and 2 by 4 inch braces spaced about 16 inches on centers. The 2 by 4 inch posts and braces are to be lined with $\frac{7}{8}$ by 8 inch tongued-and-grooved flooring, blind nailed at every bearing with 10-penny nails. All the joints are to be laid in white-lead paste and the boards firmly driven up.

Lumber.—The lumber used in the construction of the vat must be thoroughly dried and seasoned stock, free from large and loose knots, straight grained, and free from sap.

Gutters.—The gutters for the dripping pens should be made of sound stock, the bottom plank housed into the sides and ends, and the ends housed into the sides. All the joints are to be laid in white-lead paste and thoroughly nailed. Gutters are to have a 3-inch fall in 11 feet.

Bill of materials for vat and draining pens.

Vat:

Sills, 8 pieces 4 by 4 inches by 10 feet long.

Posts—

1 piece 4 by 4 inches by 16 feet long.
1 piece 4 by 4 inches by 14 feet long.
6 pieces 4 by 4 inches by 12 feet long.
5 pieces 4 by 4 inches by 10 feet long.

Braces—

1 piece 4 by 4 inches by 16 feet long.
6 pieces 4 by 4 inches by 12 feet long.
1 piece 4 by 4 inches by 10 feet long.
1 piece 4 by 4 inches by 6 feet long.

Guards—

2 pieces 2 by 8 inches by 18 feet long.
1 piece 2 by 8 inches by 16 feet long.
2 pieces 2 by 8 inches by 12 feet long.
1 piece 2 by 8 inches by 10 feet long.

Vat—Continued.

Sides—

18 pieces 2 by 8 inches by 20 feet long.
25 pieces 2 by 8 inches by 18 feet long.
2 pieces 2 by 8 inches by 16 feet long.
2 pieces 2 by 6 inches by 18 feet long.
Dressed one side and two edges.
Edges beveled for calking.

Floor—

3 pieces 2 by 10 inches by 20 feet long.
2 pieces 2 by 10 inches by 16 feet long.
1 piece 2 by 10 inches by 14 feet long.
1 piece 2 by 10 inches by 7 feet long.
1 piece 2 by 12 inches by 12 feet long.
Dressed one side and two edges.
Edges beveled for calking.

Cleats, 4 pieces 2 by 4 inches by 12 feet long.

Lumber for draining pens:

Mud sills, 10 pieces 4 by 12 inches by 2 feet long (cedar or cypress).
Sleepers, 4 pieces 6 by 6 inches by 12 feet long.
Joists, 13 pieces 2 by 12 inches by 12 feet long.
Floor, 360 feet b. m. tongue-and-groove flooring ⅞ by 8 inches, 12-foot pieces.
Cleats, 265 linear feet 1 by 3 inches.

Gutters—

Sides, 4 pieces 2 by 12 inches by 11 feet long (dressed).
Bottom and ends, 2 pieces 2 by 12 inches by 12 feet (dressed).
Bottom housed into side and ends. Ends housed into sides. All joints calked and white leaded or pitched.

Posts—

11 pieces 4 by 4 inches by 7 feet long.
2 pieces 4 by 4 inches by 8 feet long.
2 pieces 4 by 4 inches by 9 feet long.

Rails—

2 pieces 2 by 8 inches by 18 feet long.
5 pieces 2 by 8 inches by 16 feet long.
18 pieces 2 by 8 inches by 12 feet long.

Braces, 2 pieces 2 by 4 inches by 10 feet long.

Gates—

7 pieces 1 by 6 inches by 12 feet long.
6 pieces 1 by 6 inches by 10 feet long.

Hardware for vat and draining pens:

4 pairs 12-inch heavy T hinges and screws.
4 wrought-iron hooks and staples.
1 pair wrought-iron hook hinges, 12-inch, wood screw hooks, and screws.
50 pounds 20-penny wire nails.
15 pounds 10-penny wire nails.
12 square feet No. 16 galvanized iron.

The vat described is of the proper depth for cattle and horses. For sheep a platform should be provided which will rest on legs long enough to bring this platform 4 feet below the surface of the dip. This can be easily made so that it can be removed or replaced in a

few minutes to allow, if necessary, for the alternate dipping of cattle and sheep.

In selecting a site for the construction of the vat the desirability of having the ground slope away from it on one side should be kept in mind. This allows for the draining of the vat through a pipe inserted at its bottom. This drain should lead to a basin, preferably on waste land. Care should be exercised to prevent animals from drinking from the pool into which the old dip is drained and also to prevent the dip from being washed into streams used for domestic purposes.

In order to prevent the dip from becoming diluted by rains and to check evaporation, a roof of boards or canvas over the vat is desirable.

HANDWORK IN THE DESTRUCTION OF THE SPOTTED-FEVER TICK.

For the most part the use of dipping vats will furnish all facilities necessary for the eradication of the ticks. However, in certain cases, as, for instance, in the narrow valleys running some distance into the mountains, the expense of constructing dipping vats for the small number of cattle present would be prohibitive. Instead of driving these cattle considerable distances to dipping vats, it will be found sufficient to treat them thoroughly by hand methods. The procedure is simply to apply the arsenical dipping mixture liberally by means of rags, mops, or brushes, or by means of spray pumps. It may be found advisable in some cases to use oil instead of the dip, although the main reliance should be placed upon the use of the dip. Oil from Wyoming, which will be found perfectly adapted to this use, can be obtained in the Bitter Root Valley, when purchased in large quantities, at a cost of about $1.25 per barrel.

DEFINITE RECOMMENDATIONS FOR CONTROL OR ERADICATION OF THE SPOTTED-FEVER TICK IN THE BITTER ROOT VALLEY.

The following are the steps that should be followed for the control or eradication of the spotted-fever tick in the Bitter Root Valley:

(1) A campaign of education whereby all the residents of the valley will be made thoroughly familiar with the feasibility of the plan of eradication and with what it will mean in the development of the valley.

(2) The obtaining of legislation to make it possible to dip or oil all live stock in the Bitter Root Valley. In general, public opinion would be sufficient to bring about the treatment of a large majority of the animals. In a few cases objections would undoubtedly be raised by farmers. Without the treatment of all live stock, the plan would necessarily fail. For this reason it is absolutely essential to

provide such legislation as will make it possible to enforce the treatment of all the animals.

(3) The obtaining of an accurate census of the horses, cattle, sheep, mules, and dogs in the valley.

(4) The construction of 10 or more dipping vats.

(5) The providing of materials to be used in the dipping mixture.

(6) The organization of a corps of workers to carry on the operations.

(7) The systematic dipping of the horses, cattle, sheep, and dogs of the valley on a definite schedule. The time of beginning and of discontinuing this work will depend somewhat upon the seasons, but should be about as indicated below. Weekly dippings are necessary, because, as pointed out in the discussion of the life history of the tick, adults may attach to domestic animals, engorge, and drop to the ground in a minimum of eight days:

March 10.
March 17.
March 24.
March 31. (Vat refilled on this date.)
April 7.
April 14.
April 21. (Vat refilled on this date.)
April 28.
May 5.
May 12.
May 19. (Vat refilled on this date.)
May 26.
June 2.
June 9.

(8) The treatment by hand of the animals in localities remote from vats should be undertaken on this same schedule.

One season's work would certainly result in a very large reduction in the number of fever ticks present in the valley. The second season's operations would bring about still further reduction in numbers, if not practical eradication. Nevertheless, a third season's work is required to make certain of the results.

ESTIMATED EXPENSES OF PRACTICAL ERADICATION OF SPOTTED-FEVER TICK IN THE BITTER ROOT VALLEY, MONT., NOT INCLUDING THE COST OF EXPERT SUPERVISION AND NECESSARY INVESTIGATION.

The approximate cost of the work for the three seasons is indicated in the statement given herewith, which does not, however, include the cost of such expert supervision and additional investigation as are required.

First year:	
10 vats, costing $200 each	$2,000
Each vat to have a capacity of 2,000 gallons.	
Cost of filling vats four times during season, at $0.0031 per gallon.[1]	248
Salary of one superintendent, 12 months	1,800
Salaries of 10 assistants for 5 months, at $80 each	4,000
The period to be covered by these men extends from Feb. 15 to July 15.	
Incidentals	1,000
Total, first year	9,048
Second year:	
Repairs to vats	200
Cost of filling vats four times during season	248
Salary of one superintendent	1,800
Salaries of 10 assistants	4,000
Incidentals	1,000
Total, second year	7,248
Third year:	
Repairs to vats	300
Cost of filling vats four times	248
Salary of one superintendent	1,800
Salaries of 10 assistants	4,000
Incidentals	1,000
Total, third year	7,348
Grand total	23,692

It may be found that more than 10 vats will be required. In that case the output for materials would be increased somewhat.

After three seasons' operations a very small annual expenditure will be necessary to avoid reinfestation of the valley by the incoming of cattle from other places. This could be easily accomplished by employing an inspector at a salary of, say, $100 per month for six months' service each year.

SUPPLEMENTARY MEANS OF CONTROL.

The main reliance in work of controlling the spotted-fever tick must be placed upon the dipping and hand treatment of domestic animals. However, there are certain supplementary means of control which should be practiced. These are (1) the reduction in the number of rodents in the valley and (2) the clearing of the brush land along the edges of the valley.

As has been explained in this bulletin, the destruction of the rodents is not a vital part of the plan of eradication we propose.

[1] The cost of dip per gallon is computed as follows: Arsenate trioxide, 5½ cents per pound; sodium carbonate, 2 cents per pound; tar, 33⅓ cents per gallon.

Nevertheless, if the number of these animals can be reduced, it will have an important effect in lessening the number of ticks present. In addition to this reason for control, the rodents are pests of considerable importance. Their extermination from the valley, if possible, would amply repay the residents in the preventing of losses to their crops.

The conditions existing in the brushy land or "slashings" along the edge of the valley are especially favorable to the tick. Not only is shade and protection furnished, but the presence of the timber furnishes the rodent hosts favorable opportunities for multiplication. In this way the presence of the brush has an important bearing upon the abundance of ticks. If the land should be cleared, the ticks would be considerably affected. Clearing the lands will, of course, increase their value and make possible their planting in orchards or other crops without loss of time when the fever tick shall have come under subjection.

For a full list of the mammals found in and around the valley and for methods for their extermination the reader is referred to Circular 82 of the Biological Survey of this department.

It is not considered necessary to have these supplementary means of control supported by funds raised for the main operations. The work of destroying rodents and of clearing the brush lands should be conducted by residents on their own initiative. The matter should be sufficiently explained and the residents should by every means possible be encouraged to undertake the work.

NECESSITY FOR EXPERT SUPERVISION.

In the work of controlling the spotted-fever tick in the Bitter Root Valley it is absolutely essential that expert entomological supervision be provided. Since the whole campaign depends upon a knowledge of the habits and life history of ticks it must be evident that the work must be in the hands of persons who are thoroughly familiar with the subject. Among the many reasons why this expert supervision is necessary are—

(1) The proper time to begin and to discontinue the dipping or oiling must be determined. This will depend upon the seasons and the time when the tick begins to develop in the spring. Unless men are at hand to determine when to begin and when to end, much unnecessary work might be done or, what is worse, many ticks might escape.

(2) It is necessary to be certain that the dipping solution is kept up to a strength sufficient to kill and to see that the dipping is properly done. The test of the strength of the solution should be conducted by experiments the results of which could be interpreted safely only by experts.

(3) The campaign of education which should be conducted in connection with the other work can only be carried on effectively by persons who by training and experience know thoroughly the points upon which the system is based. The best work can only be done by those who have had experience in similar problems and who are familiar with data sufficient to refute such fallacious arguments as may be adduced from time to time.

(4) It is possible that means of control additional to those enumerated in this bulletin may be discovered. The chance of such discoveries and the consequent hastening of the work will be increased if persons trained in entomological work are in charge.

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